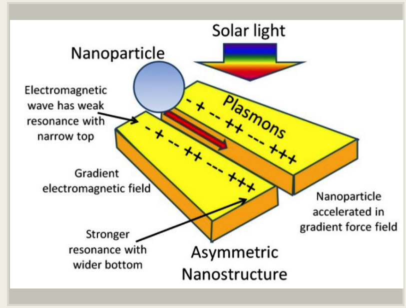
Experimental Demonstration and System Analysis for Plasmonic Force Propulsion

Completed Technology Project (2016 - 2018)

Project Introduction

One of NASA's strategic goals is expanding scientific understanding of the Earth and the universe. NASA envisions a broad class of scientific missions where extremely fine pointing and positioning of spacecraft is required, such as a single Earth observing spacecraft, deployable X-ray telescopes, exoplanet observatories, and constellations of spacecraft for Earth and deep space observations. In recognizing this, the National Research Council emphasized the need for micro-propulsion for extremely fine pointing and positioning of micro-satellites for astrophysics missions. But the full potential of these small spacecraft remains untapped because they lack maneuverability. Plasmonic force propulsion provides attitude control capability for small spacecraft with minimal power penalty and minimal mass and volume penalty. Phase I results estimate a 1-2 order of magnitude improvement over the state-of-the-art in small spacecraft proximity and pointing precision control, creating new capabilities for small spacecraft enabling NASA science and exploration missions that were previously impossible. The goal of our Phase II study is to incorporate system-level issues (i.e., thrust#noise, thermal management, thrust throttling, off-axis illumination, and plasmonic effect sensitivity) and experimental results from demonstration of nanoparticle expulsion to validate/refine our model predictions. By including these issues in our analysis our goal is to show that plasmonic space propulsion can provide the level of proximity and attitude control envisioned for future NASA nano/picosatellite missions, a level that is better than state-of-the-art approaches. Our objective is to compare higher fidelity proximity/translational and attitude control predictions for plasmonic space propulsion with state-of-the-art approaches. Specific improvements to the fidelity of our predictions include (1) incorporation of experimental plasmonic force measurements, (2) incorporation of thermal, E&M, and vibration effects on the plasmonic effect sensitivity, and (3) incorporation of off-axis illumination. Our approach is to couple results from experiments and sub-system models to quantify key propulsion metrics (noise, throttleability, etc.) and the#corresponding effect of those metrics on precision pointing and attitude control of a nano/picosatellite. We will re-evaluate mass, volume, and power requirements for plasmonic propulsion incorporating our refined assumptions, and compare with other state of-the-art control techniques. This approach to Phase II builds off the approach, models and analysis of Phase I. We will create a technology development roadmap, considering cost, risk, performance, and development time of key technologies. Our team is composed of experts in plasmonics, space propulsion, and astrodynamics. The proposed plan of work can be achieved within the proposed schedule because the proposed tasks build upon existing models and simulation tools already available to us. While the focus of the project is plasmonics for space propulsion, the proposed research will have wider application and relevance to optical nanotechnology with many non-aerospace spin-offs, such as plasmonic solar cells, thermoplasmonics for cancer thermal therapy, compact biological sensors, and photonic integrated circuits for optical communications. Plasmonics is an exploding new field of



Schematic of proposed plasmonic force propulsion concept. Sunlight is focused onto a deep-subwavelength metallic nanostructure. The resonant interaction of the light with the nanostructure excites surface plasmon polaritons tha…

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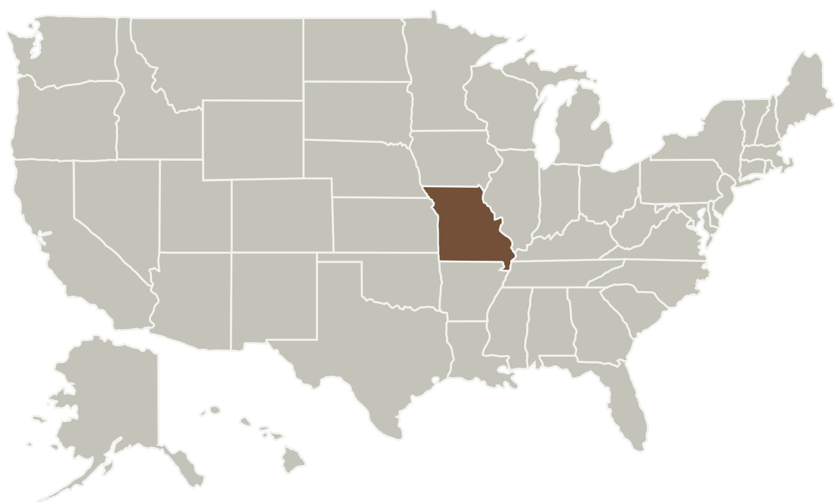
science and technology that is rapidly impacting every facet of optics and photonics, and is predicted to be one of the highest impact fields of the 21st century.

Anticipated Benefits

Plasmonic force propulsion provides attitude control capability for small spacecraft with minimal power penalty and minimal mass and volume penalty. Phase I results estimate a 1-2 order of magnitude improvement over the state-of-the-art in small spacecraft proximity and pointing precision control, creating new capabilities for small spacecraft enabling NASA science and exploration missions that were previously impossible.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Missouri-Columbia	Lead Organization	Academia	Columbia, Missouri
Missouri University of Science and Technology	Supporting Organization	Academia	Rolla, Missouri

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Missouri-Columbia

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

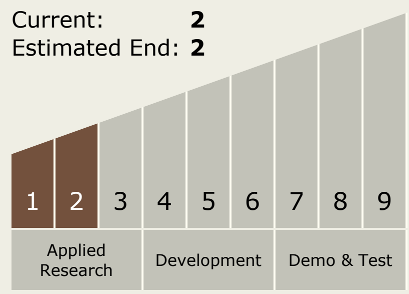
Eric A Eberly

Principal Investigator:

Joshua Rovey

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **2**



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Primary U.S. Work Locations

Missouri

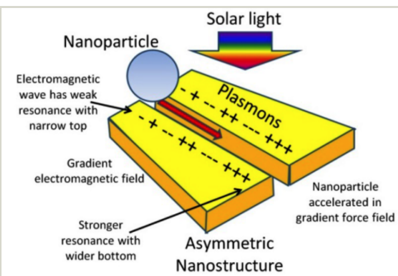
Project Transitions

August 2016: Project Start

July 2018: Closed out

Closeout Link: https://www.nasa.gov/feature/experimental-demonstration-and-system-analysis-for-plasmonic-force-propulsion

Images



Project Image
Schematic of proposed plasmonic force propulsion concept. Sunlight is focused onto a deep-subwavelength metallic nanostructure. The resonant interaction of the light with the nanostructure excites surface plasmon polaritons that generate a strong gradient optical force field. Nanoparticles are accelerated by the force field and expelled at high velocity. Nanoparticle acceleration is not due to photon pressure, but rather the strong gradient optical force field setup by surface plasmon polaritons excited by the strongly resonant light-matter interaction. Credits: J. Rovey
(https://techport.nasa.gov/image/102137)

Technology Areas

Primary:

- TX14 Thermal Management Systems
  - └ TX14.1 Cryogenic Systems
    - └ TX14.1.3 Thermal Conditioning for Sensors, Instruments, and High Efficiency Electric Motors

Target Destination

Earth

Links

NASA.gov Feature Article
(https://www.nasa.gov/feature/experimental-demonstration-and-system-analysis-for-plasmonic-force-propulsion)